

# **December 1996**

## **Preliminary Data Summary**

by      Field Research Facility

U.S. Army Corps of Engineers  
Waterways Experiment Station  
Coastal and Hydraulics Laboratory  
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# **Contents**

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Preface . . . . .	iv
1SQIntroduction . . . . .	1
2SQMeteorological Data . . . . .	7
3SQWave Data . . . . .	12
4SQCurrent Data . . . . .	17
5SQVisual Observations . . . . .	20
6SQWater Levels . . . . .	22
7SQBathymetry . . . . .	24
8SQSpecial Events . . . . .	27

## **List of Figures**

---

<u>No.</u>	
1	FRF Location Map . . . . .
2	Month at a Glance . . . . .
3	Instrument Locations at FRF . . . . .
4	Meteorological Monthly Summary . . . . .
5	Wave Heights and Periods . . . . .
6	Water Levels . . . . .
7	CRAB Profiles . . . . .
8	CRAB Profile Envelope . . . . .
9	FRF Bathymetry (3 December 96) . . . . .

## **List of Tables**

---

<u>No.</u>	
1	Instrument Status/Data Availability . . . . .
2	Gauge Locations . . . . .
3	Meteorological Data . . . . .
4	Wave Data . . . . .
5	Current Meter Data . . . . .
6	Visually Observed Current Data . . . . .
7	Visual Observations . . . . .
8	Water Levels . . . . .

# Preface

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This report provides a summary of basic oceanographic, meteorological and bottom profile data for the month. The data were obtained as part of the Measurements and Analysis work units at the U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory's Field Research Facility (FRF) in Duck, North Carolina. The FRF staff collected and analyzed these data. These summaries are intended to make the data readily available to all FRF users, and comments on their content and usefulness are invited.

**Data from these reports are now available via the World Wide Web at  
<http://www.frf.usace.army.mil>**

These web pages contain general information about the Field Research Facility and data from 1980 to the present.

Please note the new web address, <http://www.frf.usace.army.mil>

Your comments and criticisms are welcome.

# Introduction

## 1

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The U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory's (CHL) Field Research Facility (FRF) is located on the Outer Banks of North Carolina, near the village of Duck (Figure 1).

The FRF research program provides a means for obtaining high-quality field data, particularly during storms, in support of the U.S. Army Corps of Engineers' coastal engineering research missions. The research pier is a reinforced concrete structure supported on 0.9-m-diam steel piles spaced 12.2 m apart along the pier's length and 4.6 m apart across the width. The pier deck is 6.1 m wide and extends from behind the duneline to about the 6-m water depth contour at a height of 7.75 m above the National Geodetic Vertical Datum (NGVD) of the year 1929.

One of the responsibilities of the FRF research program is the collection, analysis and dissemination of data on local bathymetric, oceanographic, and meteorological conditions. This summary is intended to provide basic data as soon as possible after they are obtained. Questions and/or comments concerning the data may be directed to Mr. Clifford F. Baron at (919) 261-3511 ([c.baron@cerc.wes.army.mil](mailto:c.baron@cerc.wes.army.mil)).

Chapter 2 presents the meteorological data; Chapters 3 through 6 present oceanographic data; Chapter 7 presents nearshore profiles and bathymetry; and Chapter 8, if included, documents special events that occurred at the FRF during the month.

Table 1 is a list of instruments used and their operational status during the month. Figure 2 shows weather and ocean conditions for the month. Table 2 and Figure 3 identifies the location of the instruments. The water depths at the wave gauges and current meters vary and may be determined from information contained in Figure 9. Other installation information is contained in Table 1.

Times given in the report are referenced to eastern standard time (EST).

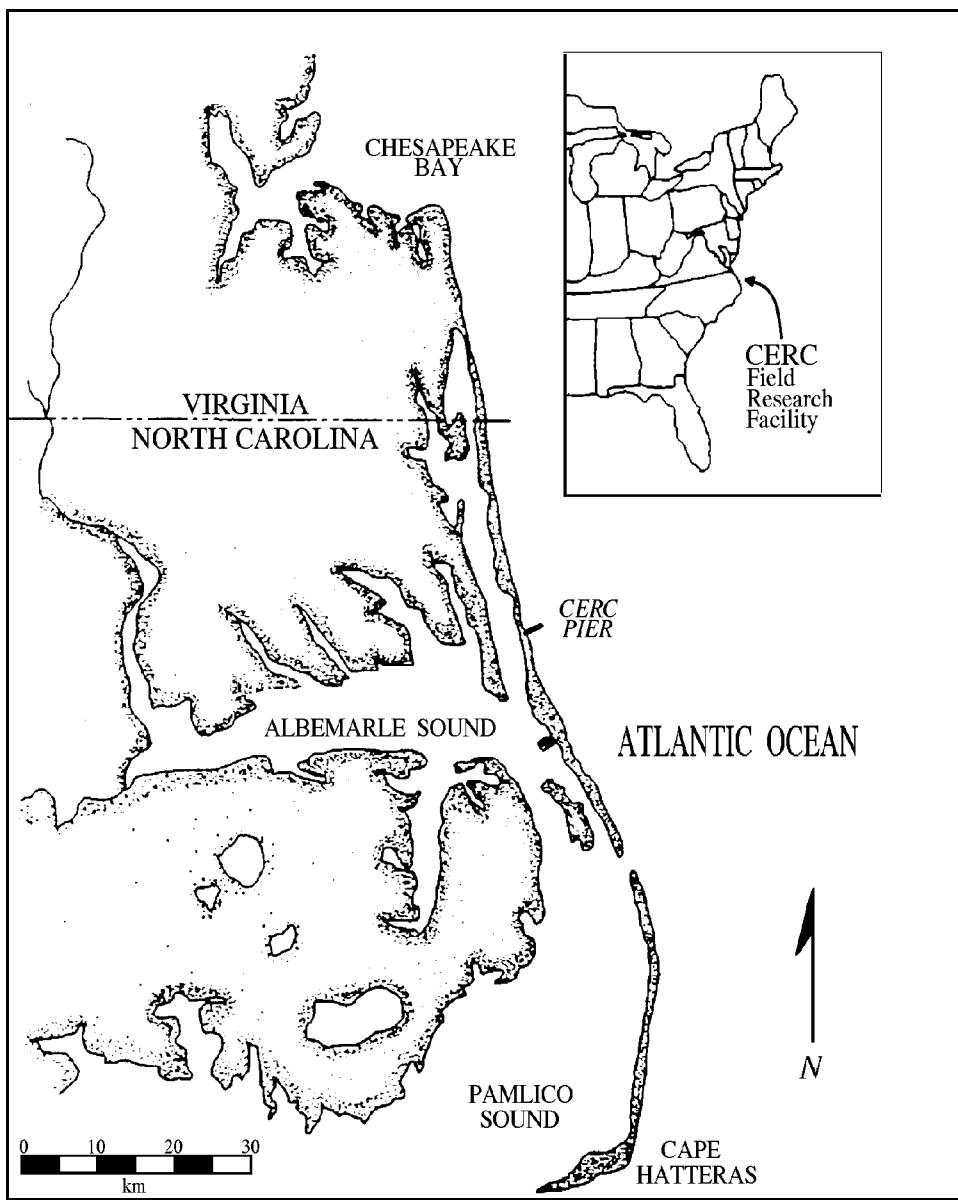


Figure 1. FRF Location Map

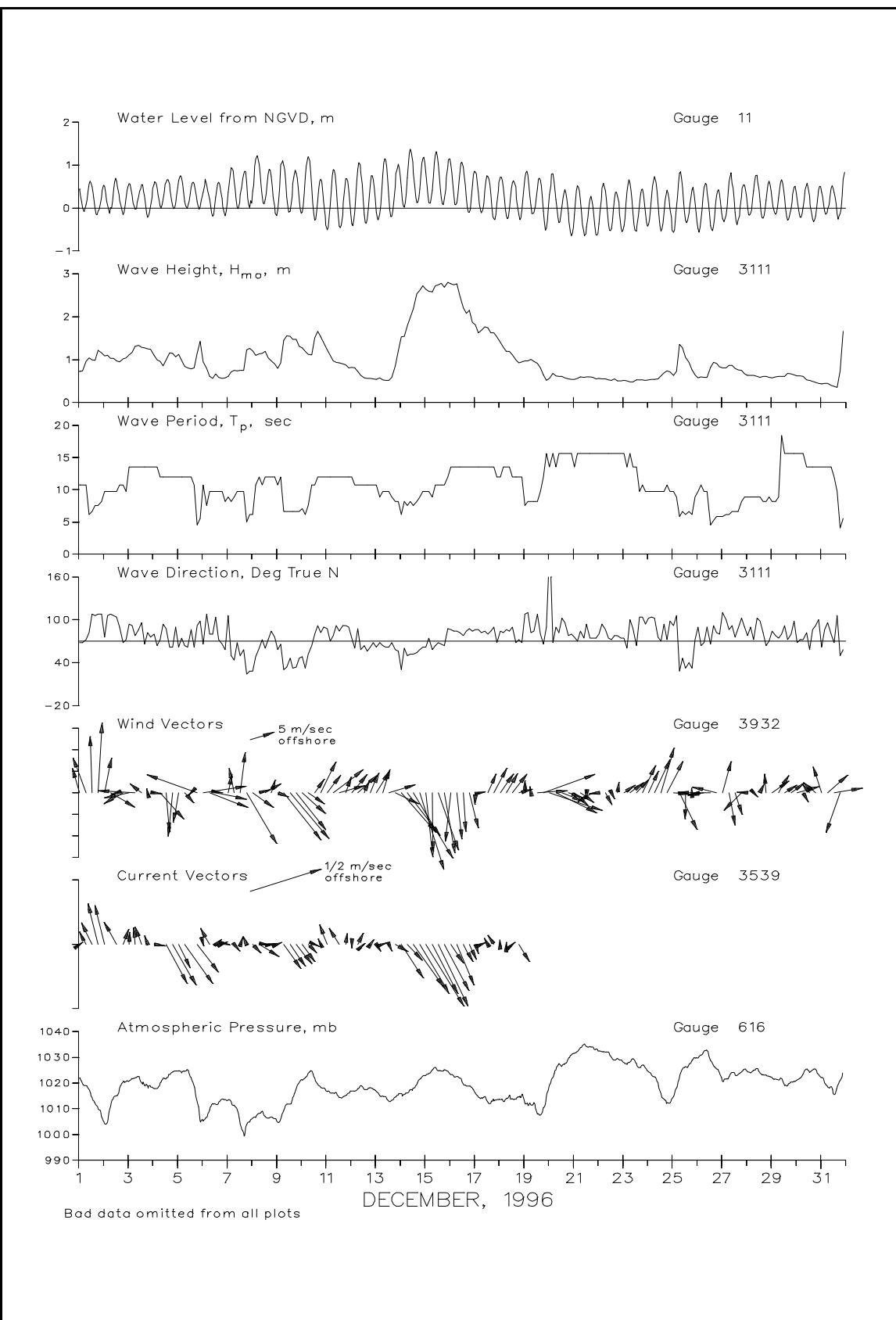


Figure 2. Month at a Glance

**Table 1**  
**Instrument Status/Data Availability**

		December 1996																																	
		Day of the month																																	
Gauge ID	Description/Remarks	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1			
616	Atmospheric Pressure	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
604	Precipitation	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
624	Air Temperature	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
3932	Anemometer	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
641	Pressure Gauge on FRF pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
625	Baylor staff on FRF pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
3111	8 Meter Array 309 m north of FRF	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
111	Pressure Gauge center of 8 Meter Array	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
630	Waverider buoy 4.0 km offshore	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	/	-	-	-	/	*	*	-	-	-	/	*	*	*	*	*	
3539	Current meter 343 m north of FRF pier (1.6 km offshore)	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
		Data Collected	*	/	/	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
11	NOAA tide gauge at end of pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Visual Observations (daily oceanographic and meteorological observations)		Daily observation	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Gauge Status      * = Operational      / = Partial      - = Non-Operational																																			
Data Collected    * = All                / = Partial        - = None																																			
Visual Observations    * = Complete      / = Partial        - = None																																			

**Table 2**  
**Gauge Locations**

Gauge*	Description	* Latitude	* Longitude	* FRF Coordinates	* Gauge Depth	* Water Depth
ID *		* Degrees N	* Degrees W	* CrossshoreT Longshore*	NGVD, m	* NGVD, m
		*	*	*	m	*
616	* Atmospheric Pressure*	36 10' 57.03"	* 75 45' 5.50"	* 11.60	* 569.00	* -----
3932	* Anemometer	* 36 11' 1.23"	* 75 44' 43.07"	* 585.20	* 517.30	* 19.50
641	* Pressure Gauge	* 36 10' 57.71"	* 75 44' 56.23"	* 239.11	* 516.64	* -1.64
625	* Baylor Staff	* 36 11' 1.04"	* 75 44' 43.72"	* 568.00	* 516.64	* Surface
3111	* 8 Meter Array North	* 36 11' 19.14"	* 75 44' 36.41"	* 915.23	* 990.16	* -7.50
	* 8 Meter Array South	* 36 11' 11.28"	* 75 44' 33.28"	* 914.20	* 735.37	* -7.42
	* 8 Meter Array East	* 36 11' 13.70"	* 75 44' 32.56"	* 954.51	* 800.58	* -7.62
	* 8 Meter Array West	* 36 11' 12.48"	* 75 44' 37.11"	* 834.66	* 800.37	* -6.98
111	* Pressure Gauge in center of 8 M Array	* 36 11' 14.06"	* 75 44' 34.39"	* 914.43	* 825.52	* -7.76
630	* Waverider Buoy	* 36 10' 5.10"	* 75 41' 59.30"	* 3934.96	* -2400.81	* Surface
3539	* Current Meter	* 36 11' 23.57"	* 75 44' 9.12"	* 1605.80	* 907.60	* -11.60
11	* NOAA Tide Gauge	* 36 11' 1.25"	* 75 44' 42.60"	* 596.49	* 514.20	* Surface
R	R	R	R	R	R	R

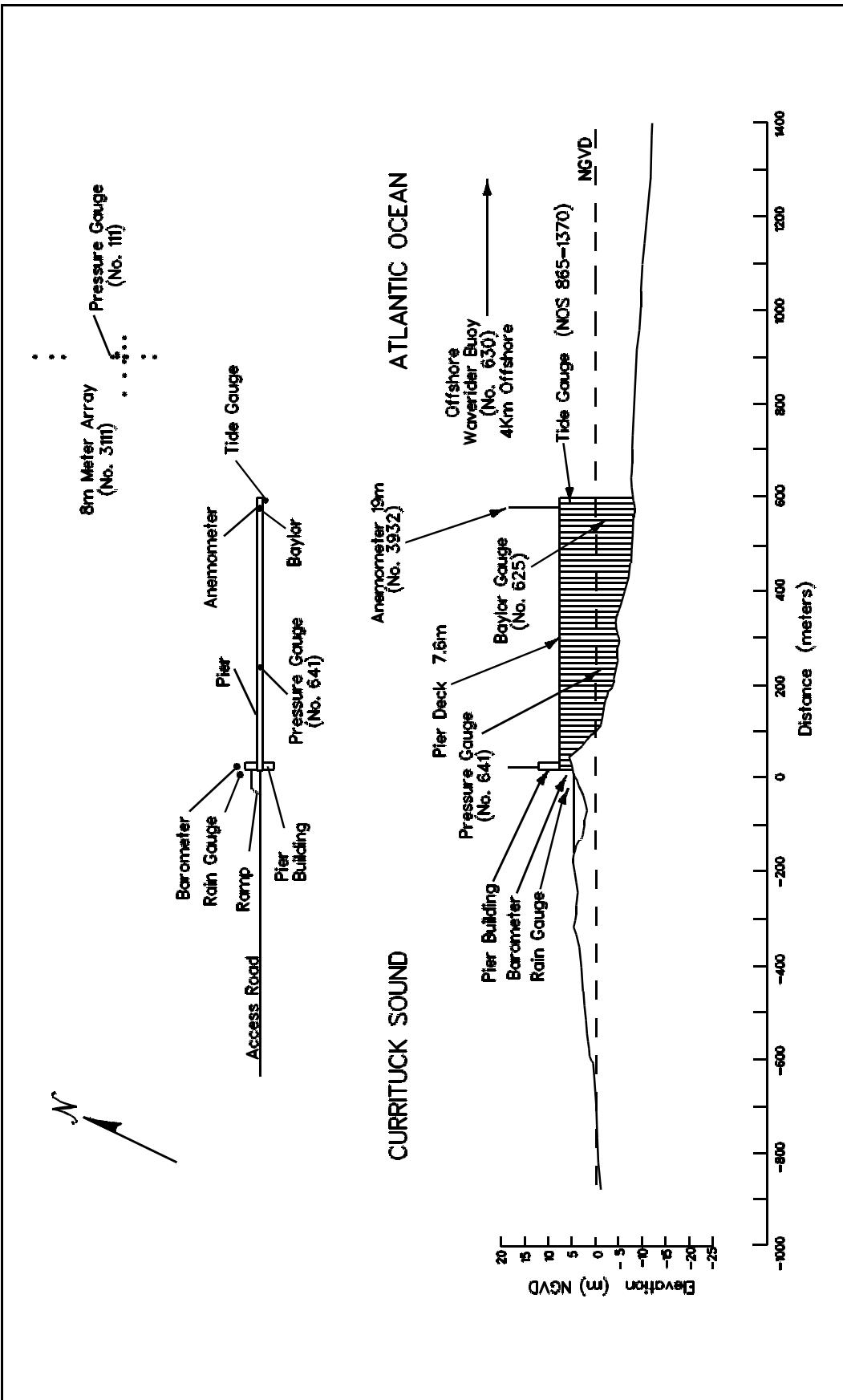


Figure 3. Instrument Locations, Elevations From NGVD

# Meteorological Data

## 2

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A variety of instruments have been installed at the FRF (Figure 3) to monitor the meteorological conditions. The data presented in Table 3 are collected and stored using a Digital Equipment Corporation VAXstation 4000. For each instrument identified in Table 1, a log is maintained and the records are stored for future reference.

Winds were measured at the end of the pier at an elevation of 19 m using a WeatherMeasure Skyvane anemometer. Monthly resultant wind speeds and directions (Figure 4) are determined by vector averaging the data. Wind directions (Table 3) indicate where the wind is coming from. Temperature and atmospheric pressure means (Table 3) are the average of the values presented for the month. Total precipitation is the sum for the month.

The following may be useful for converting the data in Table 3 to other frequently used units of measurement:

1. Millimeters (mm) to inches (in.) -  
 $mm \times .03937 = in.$
2. Millibars (mb) to inches of mercury (in. Hg) -  
 $mb \times 0.02953 = in. Hg$
3. Degrees Celsius (C) to degrees Fahrenheit (F) -  
 $(C \times 9/5) + 32 = F$
4. Meters per second (m/s) to knots (kn) -  
 $m/s \times 1.943 = kn$

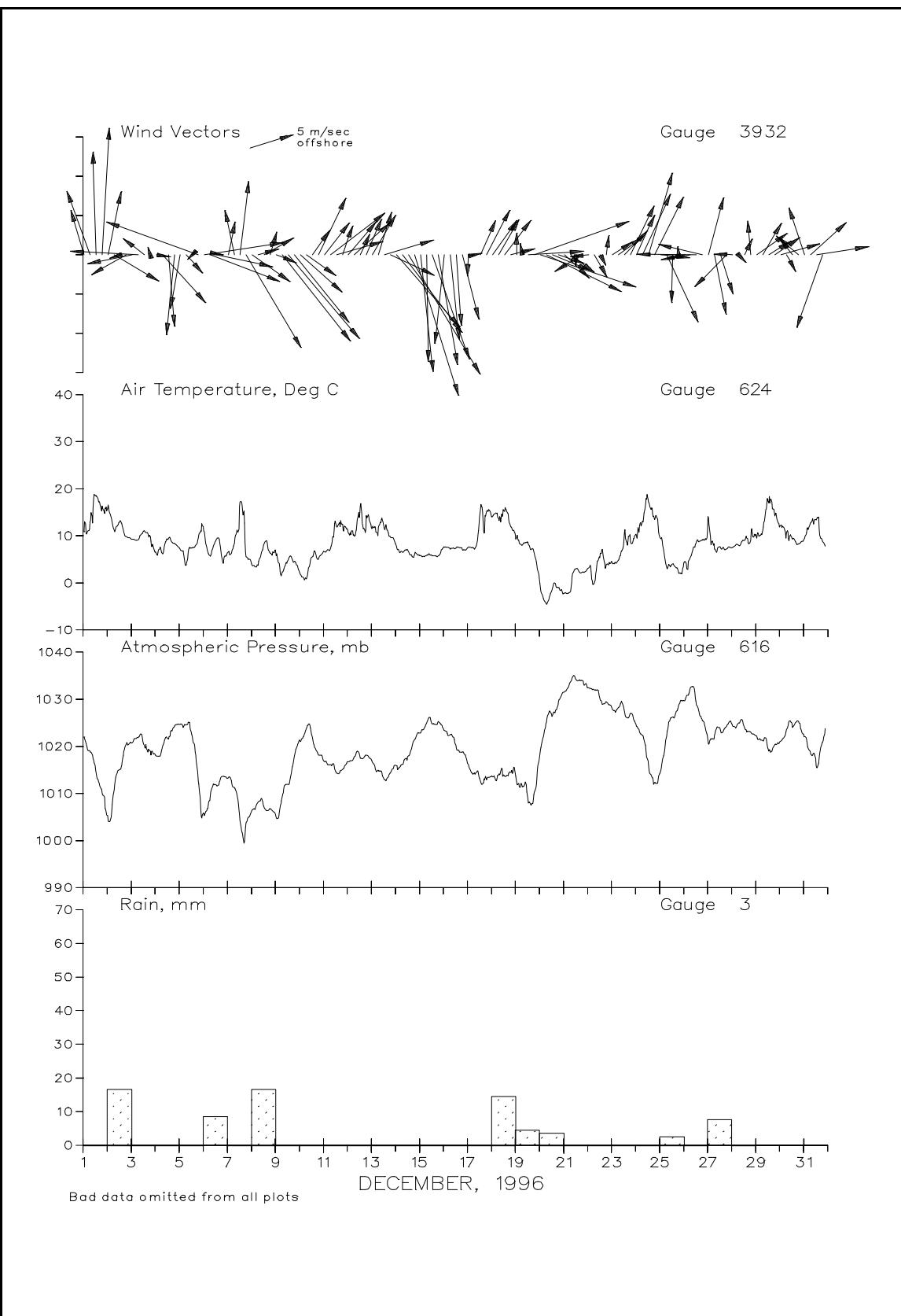


Figure 4. Meteorological Monthly Summary

**Table 3**  
**Meteorological Data**

Dec 1996						
Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
1	100	6	165	10.9	1022.0	0
	700	8	162	13.0	1019.0	0
	1300	13	178	18.6	1014.5	0
	1900	16	182	16.4	1010.1	0
	100	8	189	16.6	1004.3	0
2	700	6	304	11.2	1010.8	16
	1300	1	68	13.2	1015.1	0
	1900	5	56	9.8	1020.5	0
	100	5	76	9.3	1020.8	0
3	700	7	93	9.2	1021.9	0
	1300	3	131	11.1	1020.2	0
	1900	1	166	9.8	1019.0	0
	100	2	278	6.2	1017.9	0
4	700	8	321	6.2	1019.9	0
	1300	9	355	9.4	1021.6	0
	1900	10	4	8.4	1024.2	0
	100	7	9	7.1	1024.7	0
5	700	3	322	3.7	1024.6	0
	1300	1	41	7.5	1022.2	0
	1900	11	112	9.5	1012.7	0
	100	9	259	10.9	1005.3	0
6	700	8	1	5.6	1009.6	8
	1300	6	283	9.3	1011.8	0
	1900	0		4.8	1013.7	0
	100	4	190	6.6	1013.4	0
7	700	6	169	8.4	1011.4	0
	1300	9	185	17.2	1004.2	0
	1900	13	333	5.5	1003.8	0
	100	5	309	3.7	1006.5	0
8	700	2	251	3.8	1008.3	16
	1300	4	236	8.3	1007.0	0
	1900	3	193	6.3	1006.8	0
	100	2	1	5.8	1004.9	0
9	700	13	325	2.3	1009.4	0
	1300	13	323	4.9	1012.0	0
	1900	10	325	4.6	1017.9	0
	100	7	316	1.9	1021.1	0
10	700	4	309	0.9	1023.9	0
	1300	4	211	5.6	1021.9	0
	1900	8	202	5.0	1018.2	0

**Table 3**  
**Meteorological Data (continued)**

Dec 1996						
Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
11	100	5	214	6.7	1016.8	0
	700	8	228	7.4	1016.2	0
	1300	5	251	12.0	1014.4	0
	1900	4	197	12.5	1015.2	0
12	100	5	216	10.7	1016.8	0
	700	6	223	10.0	1017.8	0
	1300	3	201	16.4	1017.5	0
	1900	5	200	14.3	1018.2	0
13	100	6	206	11.8	1016.6	0
	700	6	195	11.9	1014.9	0
	1300	6	250	11.4	1013.0	0
	1900	5	1	9.7	1014.5	0
14	100	12	322	7.8	1016.0	0
	700	12	326	6.5	1016.2	0
	1300	17	332	6.7	1018.1	0
	1900	19	344	6.0	1021.5	0
15	100	15	354	5.9	1022.9	0
	700	14	359	5.9	1025.0	0
	1300	14	342	5.8	1024.8	0
	1900	14	351	5.7	1025.3	0
16	100	11	5	7.6	1023.4	0
	700	11	354	7.2	1022.6	0
	1300	9	356	7.6	1019.6	0
	1900	8	347	7.0	1018.8	0
17	100	3	1	7.6	1016.1	0
	700	1	257	7.2	1014.4	0
	1300	5	200	15.8	1012.6	0
	1900	6	204	15.1	1013.0	0
18	100	5	211	14.1	1013.6	0
	700	5	206	13.7	1014.0	14
	1300	5	213	15.1	1013.7	0
	1900	3	254	12.0	1014.6	0
19	100	3	180	9.7	1012.3	0
	700	1	170	8.1	1011.4	4
	1300	6	265	8.2	1008.0	0
	1900	11	247	6.3	1010.4	0
20	100	11	291	-1.1	1019.3	0
	700	9	1	-4.5	1025.1	3
	1300	5	295	-1.1	1026.6	0
	1900	3	1	-1.0	1029.6	0

**Table 3**  
**Meteorological Data (concluded)**

Dec 1996						
Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
21	100	4	317	-2.2	1031.7	0
	700	3	310	-1.8	1033.8	0
	1300	1	5	3.1	1034.1	0
	1900	4	55	2.3	1034.0	0
22	100	2	82	3.2	1032.5	0
	700	3	1	0.0	1032.1	0
	1300	1	335	6.3	1029.9	0
	1900	2	186	3.9	1029.5	0
23	100	3	232	4.2	1027.9	0
	700	4	229	4.8	1028.3	0
	1300	4	219	10.7	1027.5	0
	1900	7	202	8.7	1027.1	0
24	100	5	201	9.9	1024.3	0
	700	8	201	13.2	1022.4	0
	1300	11	194	17.1	1015.9	0
	1900	8	203	13.4	1012.4	0
25	100	3	276	9.4	1014.8	0
	700	9	337	3.3	1022.2	3
	1300	6	1	4.1	1026.3	0
	1900	1	173	2.0	1028.8	0
26	100	2	75	4.6	1029.7	0
	700	3	79	5.5	1032.5	0
	1300	7	90	8.7	1028.8	0
	1900	5	105	9.1	1025.4	0
27	100	7	192	13.9	1020.6	0
	700	8	350	7.2	1022.5	7
	1300	5	344	7.5	1023.4	0
	1900	5	40	7.2	1024.2	0
28	100	2	92	7.5	1024.4	0
	700	1	320	8.0	1025.0	0
	1300	2	202	9.1	1024.0	0
	1900	4	175	9.1	1023.1	0
29	100	4	230	9.5	1022.2	0
	700	4	207	11.2	1021.2	0
	1300	3	234	17.0	1019.0	0
	1900	3	231	14.2	1020.5	0
30	100	5	251	12.3	1021.2	0
	700	2	334	10.7	1023.6	0
	1300	3	145	9.3	1024.0	0
	1900	3	134	8.4	1025.4	0
31	100	6	163	9.5	1022.1	0
	700	6	223	12.8	1018.5	0
	1300	6	259	13.6	1015.5	0
	1900	10	17	8.7	1020.9	0
		Resultant		Mean	Mean	Total
		2	282	8.2	1019.3	71

# Wave Data

## 3

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Wave data are collected from three different sets of instruments, as shown in Table 1 and Figure 3. The first is an array of fifteen pressure gauges, collectively referred to as gauge 3111 (gauge 111 being one of them). Directional information is computed from these gauges using a iterative maximum likelihood estimator. The second is a Baylor staff gauge (625) and a pressure gauge (641), both attached to the pier. The third is a Waverider buoy (630). The data are collected, analyzed, and stored on optical disc using a Digital Equipment Corporation VAXstation 4000. Data is sampled at 2 hertz, with five contiguous 34 minute records, for a total collection period of nearly 2 hours and 51 minutes. This report reflects the data collection periods of 0100, 0700, 1300, and 1900 EST. The results are based only on the first 34 minute record. The exception is the 8 Meter Array (3111) which condenses the first four records into one statistical value.

Wave height  $H_{mo}$  is an energy-based statistic equal to four times the standard deviation of the sea surface elevations. Wave height reported from the pressure gauge has been compensated for hydrodynamic attenuation using linear wave theory. Wave period is identified from the computation of a variance (energy) spectrum with 60 degrees of freedom calculated from a 34-min record. Peak wave period  $T_p$  is defined as the period associated with the maximum energy in the spectrum.

Table 4 presents the wave heights and periods for each wave record obtained at 6 hr intervals during the month. The monthly means and standard deviations from the means shown in Table 4 are average values computed from this data. Figure 5 is a time history of all  $H_{mo}$  and  $T_p$  values obtained for all gauges.

Differences in wave periods between wave gauges (Table 4 and Figure 5) may be the result of wave breaking, wave reformation, the presence of multiple wave trains containing nearly equal energy, and statistical variations in spectral estimations.

**Table 4**  
**Wave Data**

Dec 1996										
Day	Hour	641		625		3111			630	
		Pressure Hmo,m	Gauge Tp,sec	Baylor Hmo,m	Gauge Tp,sec	8 Meter Hmo,m	Array Tp,sec	Dir,TN	Waverider Hmo,m	Tp,sec
1	0100	0.38	10.7	0.70	10.7	0.72	10.8	68	0.86	10.6
	0700	0.51	5.9	0.88	10.7	0.96	10.8	72	1.15	10.1
	1300	0.66	6.3	0.96	6.5	0.99	6.6	108	1.29	6.3
	1900	0.72	7.6	1.07	7.8	1.21	7.6	108	1.46	7.2
2	0100	0.70	8.6	1.00	9.5	1.09	9.8	76	1.41	10.1
	0700	0.63	11.2	0.93	10.7	1.03	9.8	108	1.25	10.1
	1300	0.64	10.3	0.94	9.9	0.97	9.8	104	1.13	9.1
	1900	0.62	9.9	1.01	9.9	1.01	10.8	68	1.13	10.1
3	0100	0.73	14.3	1.07	13.5	1.11	13.6	94	1.24	13.4
	0700	0.74	13.5	1.19	13.5	1.30	13.6	78	1.44	12.6
	1300	0.83	14.3	1.17	13.5	1.28	13.6	96	1.36	13.4
	1900	0.71	13.5	1.08	13.5	1.26	13.6	82	1.31	13.4
4	0100	0.73	12.9	1.11	12.9	1.10	13.6	80	1.22	12.6
	0700	0.48	12.9	0.82	12.9	0.96	12.0	72	0.97	13.4
	1300	0.59	12.2	0.91	12.2	0.99	12.0	88	1.41	12.6
	1900	0.83	5.5	1.13	11.7	1.14	12.0	62	1.57	11.8
5	0100	0.90	6.0	1.13	12.2	1.12	12.0	62	1.43	5.9
	0700	0.64	5.6	0.84	11.7	0.84	12.0	64	1.04	11.8
	1300	0.51	6.0	0.75	11.2	0.79	12.0	86	0.82	11.8
	1900	0.65	4.1	1.16	11.2	1.14	4.6	92	1.28	11.8
6	0100	0.65	5.7	1.05	11.2	0.95	10.8	66	1.37	5.3
	0700	0.34	10.7	0.61	9.9	0.61	9.8	80	0.97	11.2
	1300	0.40	8.9	0.63	10.3	0.67	9.8	104	0.82	10.6
	1900	0.30	8.3	0.54	9.9	0.56	9.8	66	0.67	10.1
7	0100	0.38	7.6	0.56	8.3	0.61	8.9	106	0.68	7.7
	0700	0.51	8.1	0.77	8.6	0.75	8.9	44	0.98	8.4
	1300	0.44	9.9	0.70	8.9	0.75	9.8	50	0.93	9.1
	1900	0.76	5.2	1.10	5.1	1.22	5.0	24	1.60	4.8
8	0100	1.04	6.8	1.22	8.3	1.21	6.2	28	1.76	5.9
	0700	0.87	11.7	1.04	12.2	1.13	12.0	60	inoperative	
	1300	0.75	12.9	1.09	12.9	1.19	12.0	60	1.26	10.1
	1900	0.62	12.9	0.91	11.2	0.97	12.0	84	1.00	11.8
9	0100	0.43	11.7	0.73	12.2	0.79	10.8	58	0.76	11.8
	0700	1.01	6.5	1.26	6.0	1.45	6.6	30	1.88	5.6
	1300	1.22	6.8	1.47	6.3	1.55	6.6	46	1.91	6.3
	1900	1.33	6.6	1.43	6.1	1.47	6.6	34	1.88	6.7
10	0100	0.95	6.8	1.18	6.8	1.27	7.1	48	1.60	6.7
	0700	0.94	7.0	1.08	7.0	1.13	7.6	52	1.52	7.2
	1300	0.89	10.7	1.20	10.7	1.50	10.8	80	1.41	10.1
	1900	0.88	11.7	1.41	12.2	1.52	12.0	82	1.63	11.8

**Table 4**  
**Wave Data (continued)**

Dec 1996											
Day	Hour	641 Pressure Gauge		625 Baylor Gauge		3111 8 Meter Array			630 Waverider		
		Hmo,m	Tp,sec	Hmo,m	Tp,sec	Hmo,m	Tp,sec	Dir,TN	Hmo,m	Tp,sec	
11	0100	0.64	12.2	1.15	11.7	1.22	12.0	88	1.22	12.6	
	0700	0.52	11.7	0.89	11.7	0.97	12.0	78	1.07	11.2	
	1300	0.41	12.2	0.88	12.2	0.92	12.0	84	0.89	13.4	
	1900	0.49	12.2	0.79	12.2	0.88	12.0	92	0.86	11.2	
12	0100	0.38	11.2	0.76	11.7	0.81	12.0	74			
	0700	0.38	10.7	0.69	10.7	0.72	10.8	88			
	1300	0.25	11.7	0.55	11.2	0.58	10.8	64			
	1900	0.29	11.2	0.51	11.2	0.56	10.8	62			
13	0100	0.23	9.9	0.51	9.5	0.55	10.8	62			
	0700	0.31	9.5	0.50	8.9	0.52	9.8	64			
	1300	0.30	19.7	0.46	10.7	0.52	9.8	62			
	1900	0.47	8.6	0.72	8.9	0.86	8.2	58			
14	0100	1.12	5.7	1.43	8.3	1.53	6.2	30	inoperative		
	0700	1.37	7.4	1.64	7.8	1.78	7.6	50			
	1300	1.50	8.3	2.04	8.3	2.17	7.6	52			
	1900	1.46	7.6	2.34	8.9	2.61	8.9	58			
15	0100	1.57	9.5	2.53	9.9	2.64	9.8	62			
	0700	1.30	10.7	2.37	10.3	2.58	8.9	58			
	1300	1.55	10.7	2.51	11.2	2.74	10.8	68			
	1900	1.23	11.2	2.45	11.7	2.69	10.8	64			
16	0100	1.52	12.9	2.66	12.9	2.77	13.6	86			
	0700	1.43	13.5	2.51	13.5	2.76	13.6	84			
	1300	1.57	13.5	2.13	13.5	2.20	13.6	78			
	1900	1.35	14.3	1.99	14.3	2.15	13.6	88			
17	0100	1.26	13.5	1.74	13.5	1.81	13.6	86			
	0700	0.94	13.5	1.56	13.5	1.68	13.6	82			
	1300	1.10	12.9	1.60	12.9	1.74	13.6	80	1.88	13.4	
	1900	0.84	13.5	1.43	12.9	1.63	13.6	90	1.71	13.4	
18	0100	0.83	12.9	1.28	12.9	1.40	12.0	84	1.50	11.8	
	0700	0.64	12.9	1.05	12.2	1.19	13.6	86	1.35	11.8	
	1300	0.65	13.5	0.98	11.7	1.11	12.0	90	1.33	13.4	
	1900	0.45	12.9	0.90	12.2	0.93	12.0	72	1.09	13.4	
19	0100	0.56	12.2	0.92	12.2	0.97	7.6	108	1.11	7.2	
	0700	0.51	8.3	0.87	8.3	1.01	8.2	82	1.18	8.4	
	1300	0.54	8.9	0.79	8.3	0.91	8.2	108	1.13	9.1	
	1900	0.37	15.1	0.63	8.3	0.65	12.0	66	0.96	8.4	
20	0100	0.34	15.1	0.57	12.2	0.56	13.6	224	0.98	3.4	
	0700	0.53	5.6	0.67	3.8	0.62	13.6	90	1.04	5.6	
	1300	0.36	15.1	0.63	15.1	0.61	15.7	102	0.81	8.4	
	1900	0.28	15.1	0.51	15.1	0.55	15.7	78	0.67	14.3	

**Table 4**  
**Wave Data (concluded)**

Dec 1996										
Day	Hour	641 Pressure Gauge		625 Baylor Gauge		3111 8 Meter Array			630 Waverider	
		Hmo,m	Tp,sec	Hmo,m	Tp,sec	Hmo,m	Tp,sec	Dir,TN	Hmo,m	Tp,sec
21	0100	0.29	16.0	0.54	15.1	0.54	13.6	76	inoperative	
	0700	0.36	16.0	0.56	15.1	0.59	15.7	84		
	1300	0.31	16.0	0.57	15.1	0.60	15.7	94		
	1900	0.32	16.0	0.56	15.1	0.58	15.7	74		
22	0100	0.31	16.0	0.61	16.0	0.57	15.7	80		
	0700	0.30	15.1	0.52	10.7	0.55	15.7	86		
	1300	0.24	14.3	0.51	15.1	0.52	15.7	72		
	1900	0.26	15.1	0.47	15.1	0.51	15.7	78		
23	0100	0.20	14.3	0.47	15.1	0.51	15.7	74		
	0700	0.25	15.1	0.41	14.3	0.48	15.7	100	inoperative	
	1300	0.20	14.3	0.46	14.3	0.52	13.6	64		
	1900	0.28	10.3	0.48	10.7	0.53	10.8	104		
24	0100	0.21	10.3	0.46	9.9	0.53	9.8	102		
	0700	0.32	9.9	0.51	9.2	0.54	9.8	102		
	1300	0.33	7.0	0.56	9.9	0.62	9.8	70		
	1900	0.46	7.4	0.70	7.2	0.73	10.8	72		
25	0100	0.29	7.4	0.60	9.5	0.63	9.8	92		
	0700	0.93	5.4	1.16	5.4	1.36	5.9	28	1.76	5.9
	1300	0.77	6.1	1.00	6.1	1.05	6.2	32	1.39	5.6
	1900	0.57	6.3	0.78	6.3	0.76	6.2	32	1.04	5.9
26	0100	0.32	4.8	0.51	8.3	0.58	9.8	90	0.79	5.3
	0700	0.33	9.9	0.55	9.9	0.59	9.8	68	0.66	10.1
	1300	0.40	4.1	0.87	4.3	0.82	4.6	66	1.03	4.2
	1900	0.52	5.6	0.95	5.6	0.91	5.9	82	1.19	5.6
27	0100	0.37	6.5	0.75	6.0	0.81	5.9	110	0.96	5.6
	0700	0.48	6.3	0.86	6.5	0.86	6.2	86	1.08	6.7
	1300	0.42	6.1	0.83	6.5	0.80	6.6	76	1.09	6.3
	1900	0.45	9.5	0.72	7.4	0.74	8.2	102	0.94	6.3
28	0100	0.32	9.5	0.62	8.9	0.64	8.9	78	0.78	9.1
	0700	0.32	8.6	0.61	8.6	0.63	8.9	72	0.76	8.4
	1300	0.29	9.2	0.58	8.9	0.58	8.9	98	0.71	9.1
	1900	0.29	8.6	0.58	8.6	0.61	8.2	64	0.69	8.4
29	0100	0.29	19.7	0.54	7.6	0.57	8.2	84	0.67	8.4
	0700	0.32	18.3	0.55	8.6	0.61	8.9	74	0.67	8.4
	1300	0.33	17.1	0.53	16.0	0.61	15.7	92	0.65	16.7
	1900	0.42	16.0	0.67	16.0	0.67	15.7	80	0.66	15.4
30	0100	0.38	15.1	0.63	15.1	0.62	15.7	68	0.70	15.4
	0700	0.33	15.1	0.55	14.3	0.61	15.7	72	0.61	15.4
	1300	0.26	14.3	0.42	14.3	0.51	13.6	58	0.52	15.4
	1900	0.23	13.5	0.44	13.5	0.46	13.6	92	0.46	13.4
31	0100	0.25	13.5	0.41	13.5	0.44	13.6	62	0.50	13.4
	0700	0.24	9.9	0.46	8.6	0.45	13.6	96	0.54	11.8
	1300	0.21	12.9	0.38	12.9	0.37	12.0	68	0.44	9.1
	1900	0.45	3.9	0.68	3.5	0.74	4.1	50	0.89	3.5
Mean		0.61	10.7	0.95	10.7	1.01	10.9	76	1.10	9.7
Std dev		0.36	3.6	0.52	3.0	0.56	3.0	23	0.37	3.2

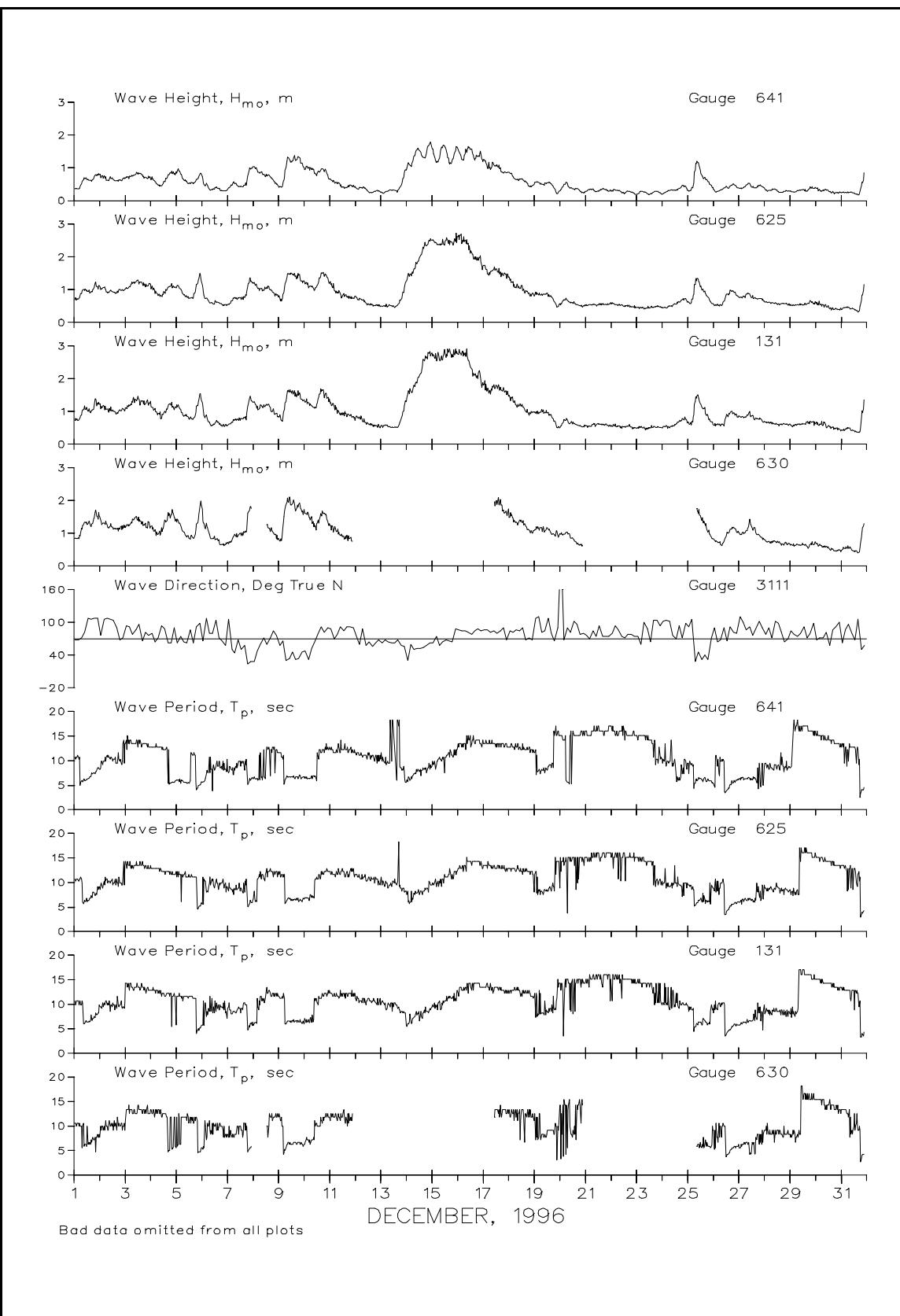


Figure 5. Wave Heights and Periods

# Current Data

## 4

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Current data (Table 5) are collected from a Marsh-McBirney electromagnetic biaxial current meter and by visually observing the movement of small drogues on the water surface in the surf and at the seaward end of the pier, as well as 500 m updrift of the pier, approximately 12 m offshore (Table 6).

Since the shoreline orientation is approximately N20W, longshore currents flow either toward 340 deg (i.e. northward) or toward 160 deg (i.e. southward). Similarly, cross-shore currents are either onshore (westward) or offshore (eastward). All current speeds are given in centimeters per second (cm/sec). Resultant speeds and directions are determined by vector averaging the cross-shore and longshore data. Current directions indicate the direction that the current is moving towards. Current data are plotted in Figure 2.

**Table 5**  
**Current Meter Data - Gauge 3539**

DECEMBER 1996													
		Cross	Long		Cross	Long		Cross	Long				
Day	Time	Shore	Shore	Speed	Dir	Shore	Shore	Speed	Dir	Shore	Shore	Speed	Dir
1	100	-1	0	3	50	1300	2	-13	14	331	22	100	
	700	1	-10	11	336	1900	-3	-7	9	9		700	
	1300	1	-17	18	337	12	100	1	3	3	181		1300
	1900	-3	-31	32	347	700	-5	-6	9	22		1900	
2	100	-3	-30	31	348	1300	0	0	0		23	100	
	700	inoperative				1900	-2	-2	4	33		700	inoperative
	1300	2	-18	19	334	13	100	0	6	6	151		1300
	1900	-7	-8	12	19	700	-2	0	3	70		1900	
3	100	-3	-8	9	3	1300	0	6	6	158	24	100	
	700	-2	-11	13	356	1900	-5	8	10	123		700	
	1300	0	-13	14	342	14	100	-4	29	30	151		1300
	1900	0	-6	7	344	700	-4	15	16	141		1900	
4	100	-6	4	8	97	1300	-7	38	39	149	25	100	
	700	inoperative				1900	-4	42	43	153		700	
	1300	-2	33	33	155	15	100	-7	54	54	152		1300
	1900	-3	35	35	153	700	-2	42	42	156		1900	
5	100	0	20	20	157	1300	-1	52	52	157	26	100	inoperative
	700	-6	35	36	148	1900	-2	39	39	156		700	
	1300	inoperative				16	100	-2	17	17	150		1300
	1900	-5	25	26	147	700	0	34	34	160		1900	
6	100	0	2	2	165	1300	-1	15	15	154	27	100	
	700	2	-13	14	334	1900	0	13	13	157		700	
	1300	-4	-1	6	45	17	100	1	7	7	164		1300
	1900	-3	0	4	62	700	-2	0	3	62		1900	
7	100	0	1	1	105	1300	1	-4	5	334	28	100	
	700	-1	6	6	145	1900	1	-7	8	330		700	
	1300	-2	-3	6	15	18	100	0	-2	3	359		1300
	1900	0	-6	7	338	700	0	0	0			1900	
8	100	-2	8	9	141	1300	-1	0	2	45	29	100	inoperative
	700	-8	13	16	125	1900	-1	15	15	152		700	
	1300	-2	2	3	102	19	100					1300	
	1900	-2	1	3	79							1900	
9	100	-2	0	3	64	1300					30	100	
	700	-3	22	22	149	1900						700	
	1300	-3	20	20	149	20	100	inoperative				1300	
	1900	-4	18	18	145							1900	
10	100	-2	16	16	149	1300					31	100	
	700	-2	8	9	140	1900						700	
	1300	-1	3	3	116	21	100					1300	
	1900	0	-4	5	337							1900	
11	100	0	-15	16	342	1300							
	700	inoperative				1900							

KEY:

- +cross-shore = offshore, cm/sec
- cross-shore = onshore, cm/sec
- +longshore = south, cm/sec
- longshore = north, cm/sec
- Speed = Resultant speed, cm/sec
- Dir = Resultant direction, degrees true north

**Table 6**  
**Visually Observed Current Data**

Dec 1996												
Day	Pier End				Mid-Surf Zone				Beach			
	Cross Shore	Long Shore	Speed	Dir	Cross Shore	Long Shore	Speed	Dir	Location	Speed	Dir	
1	0	-41	41	340	0	-76	76	340	South	52	N	
2	0	0	0		-20	-68	71	323	South	28	N	
3	-8	-28	29	323	-11	-38	40	323	South	6	N	
4	0	76	76	160	18	30	36	129	North	21	S	
5	-4	36	36	166	0	0	0		North	18	S	
6	17	14	22	110	-38	-51	63	303	South	32	S	
7	5	-15	16	359	18	-36	40	7	South	2	N	
8	0	0	0		0	0	0		North	32	S	
9	0	102	102	160	0	152	152	160	North	107	S	
10	9	30	32	143	-14	47	49	177	North	49	S	
11	10	-34	35	357	14	-47	49	357	South	21	N	
12	5	-16	17	357	1	-9	9	346	South	15	N	
13	7	-6	10	30	0	-27	27	340	South	12	N	
14	0	87	87	160	0	102	102	160	North	79	S	
15	0	122	122	160	0	122	122	160	North	61	S	
16	0	87	87	160	0	87	87	160	North	20	S	
17	0	0	0		-23	-76	80	323	South	18	N	
18	6	-5	8	30	-15	-51	53	323	South	35	N	
19	7	24	25	143	0	0	0		South	12	N	
20	no observation				39	44	59	118	North	18	S	
21	-5	51	51	166	13	27	30	133	North	38	N	
22	0	32	32	160	0	0	0		South	25	S	
23	20	20	29	70	-6	-41	41	331	South	8	N	
24	0	-76	76	340	0	-61	61	340	South	19	N	
25	0	76	76	160	0	87	87	160	North	9	S	
26	0	-30	30	340	-7	-44	44	331	South	13	N	
27	0	51	51	160	4	-29	29	349	South	18	N	
28	-6	38	39	169	0	-22	22	340	South	13	N	
29	0	14	14	160	10	-38	39	354	South	10	N	
30	6	-29	30	351	6	-24	25	354	South	19	N	
31	-4	-14	14	323	-3	-17	18	329	South	5	N	

KEY:

- +cross-shore = offshore, cm/sec
- cross-shore = onshore, cm/sec
- +longshore = south, cm/sec
- longshore = north, cm/sec
- Speed = Resultant speed, cm/sec
- Dir = Resultant direction, degrees true north

# Visual Observations

## 5

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Visual wave direction measurements (Table 7) of both the primary wave train (i.e. that having the higher wave heights) and the secondary wave train (which must be clearly distinguishable as a wave train separate from the primary waves but not surface chop or capillary waves) are taken daily at the seaward end of the pier. The pier axis (considered perpendicular to the beach at the FRF) is oriented 70 deg east of true north; consequently, wave angles greater than 70 deg indicate that the waves were coming from the south side of the pier.

The width of the surf zone (seawardmost breaker position to shoreline) is determined from the pier deck.

Measurements of surface water temperature, density, and depth of visibility are also taken daily at the seaward end of the pier. A Bucket Thermometer is lowered about 0.3 m into the water and allowed to remain for at least one minute. The temperature is then read, and a hydrometer is used to determine the density. A Secchi disc is used to determine the depth of visibility.

**Table 7**  
**Visual Observations**

Dec 1996							
Day	Time	Wave Approach Angle at Pier End deg from True N		Water Characteristics at Pier End			
		Primary	Secondary	Width of Surf Zone,m	Temp.,C	Density g/cc	Secchi Vis.,m
1	0850	90	120	82	10.6	1.0222	1.5
2	0710	80		67	11.4	1.0234	1.2
3	0720	75		73	12.8	1.0238	0.6
4	0730	70		67	8.9	1.0202	0.9
5	0750	50		85	8.9	1.0191	0.9
6	0735	80	30	61	10.6	1.0237	0.6
7	0730	60	120	73	10.0	1.0225	1.5
8	0910	50		101	10.0	1.0230	3.4
9	0745	30		91	9.4	1.0226	0.6
10	0740	50		88	8.1	1.0220	0.6
11	0740	90		40	8.9	1.0233	0.6
12	0730	70	115	47	10.0	1.0234	1.2
13	0750	90	120	9	10.0	1.0233	1.5
14	0915	40		98	9.4	1.0224	0.3
15	0940	40	10	369	8.1	1.0201	0.3
16	0725	60	20	482	7.8	1.0194	0.0
17	0715	75	40	280	8.3	1.0218	0.0
18	0800	80		277	8.9	1.0237	0.6
19	0755	100		73	7.8	1.0216	1.5
20	0745	100	30	55	7.8	1.0224	0.6
21	1005	45	65	61	6.4	1.0196	1.5
22	1145	95		61	6.7	1.0194	1.5
23	1100	none	visible	52	7.2	1.0204	1.8
24	0920	80	130	50	9.4	1.0236	0.6
25	0850	50		110	8.3	1.0235	0.3
26	0710	95		46	8.3	1.0242	0.3
27	0745	100	30	62	8.3	1.0216	1.8
28	0750	90	55	43	8.3	1.0200	2.1
29	0707	70		49	8.9	1.0220	1.8
30	0700	75	40	49	9.4	1.0232	1.8
31	0703	70		18	9.4	1.0232	1.8

# Water Levels

## 6

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Since 1978, the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) has operated a primary tide station (No. 865-1370) at the seaward end of the FRF pier. A NOS acoustic tide gauge (Next Generation Water Level Measurement System, NGWLMS) is used to collect water level data every 6 minutes throughout the month.

The variation in water level during the month is shown in Figure 6 along with a list of means and extreme values. This presentation is useful in identifying effects of both meteorological and astronomical forces on the open coast water level. Table 8 contains the range, high, low, and mean water level for each 12.42-hr tidal cycle.

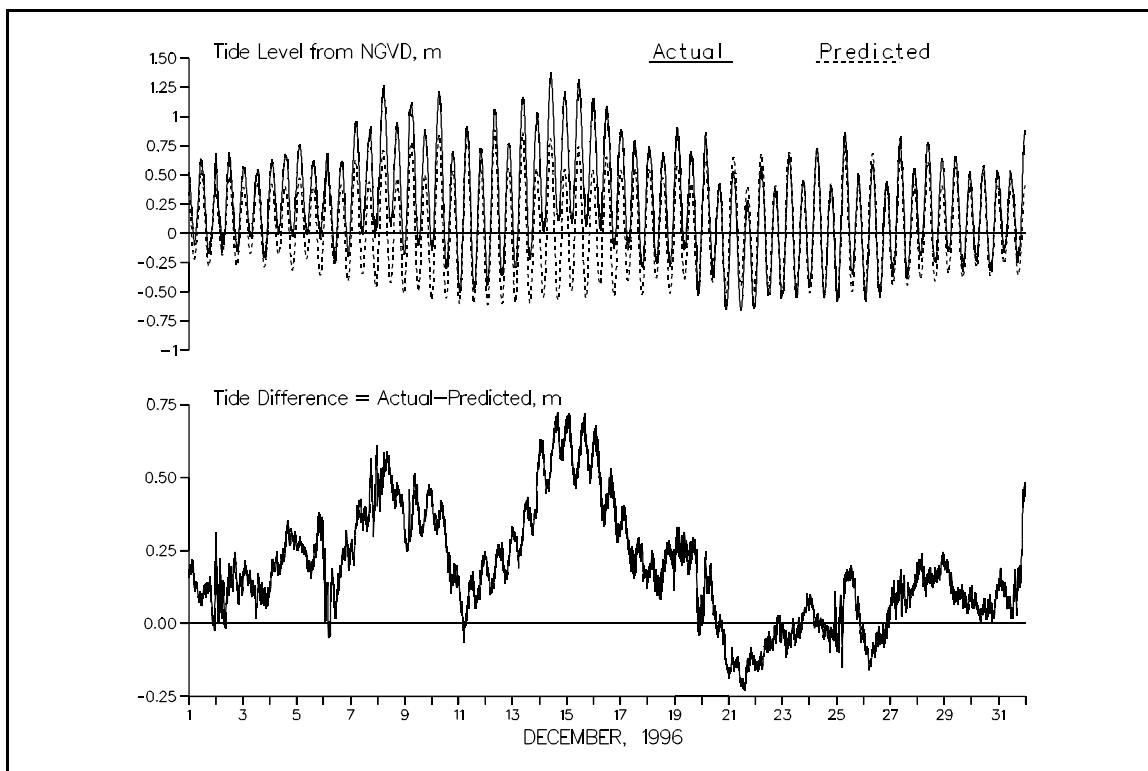


Figure 6. Water Level Variation

**Table 8**  
**Water Levels, m NGVD**

DEC 1996 Tide Levels																
Day	High			Low			Mean	Range	High			Low			Mean	Range
	Time	m	Day	Time	m	Day			Time	m	Day	Time	m	Day		
1	1048	0.64	1	0512	-0.10	0.27	0.74	17	0024	0.89	16	1824	-0.14	0.39	1.02	
2	0018	0.69	1	1742	-0.17	0.15	0.86	17	1242	0.80	17	0648	-0.14	0.33	0.94	
2	1200	0.69	2	0530	-0.17	0.26	0.86	18	0124	0.74	17	1942	-0.29	0.23	1.04	
3	0042	0.57	2	1900	-0.16	0.22	0.73	18	1354	0.69	18	0830	-0.26	0.22	0.96	
3	1306	0.55	3	0748	-0.04	0.25	0.59	19	0248	0.91	18	1948	-0.28	0.29	1.19	
4	0212	0.63	3	1900	-0.21	0.21	0.84	19	1506	0.71	19	0806	-0.14	0.27	0.85	
4	1354	0.68	4	0730	-0.02	0.35	0.70	20	0330	0.87	19	2106	-0.54	0.17	1.40	
5	0312	0.76	4	2012	-0.03	0.36	0.79	20	1612	0.43	20	1030	-0.38	0.04	0.81	
5	1536	0.62	5	0924	-0.01	0.31	0.63	21	0412	0.53	20	2212	-0.66	-0.06	1.19	
6	0336	0.69	5	2124	-0.06	0.29	0.74	21	1654	0.28	21	1106	-0.66	-0.19	0.94	
6	1612	0.62	6	1012	-0.25	0.22	0.87	22	0512	0.58	21	2242	-0.64	-0.05	1.22	
7	0430	0.96	6	2212	-0.20	0.40	1.15	22	1730	0.39	22	1118	-0.54	-0.08	0.93	
7	1742	0.92	7	1100	-0.01	0.44	0.93	23	0600	0.67	22	2254	-0.56	0.04	1.22	
8	0536	1.26	7	2154	-0.04	0.60	1.30	23	1830	0.46	23	1230	-0.55	-0.04	1.01	
8	1724	0.95	8	1124	0.05	0.49	0.89	24	0636	0.73	24	0024	-0.44	0.13	1.17	
9	0612	1.12	8	2342	-0.18	0.48	1.30	24	1854	0.41	24	1254	-0.55	-0.06	0.97	
9	1748	0.89	9	1230	-0.10	0.39	1.00	25	0742	0.86	25	0036	-0.58	0.14	1.44	
10	0642	1.22	10	0030	-0.15	0.52	1.37	25	1918	0.51	25	1412	-0.35	0.05	0.87	
10	1842	0.70	10	1318	-0.30	0.21	1.00	26	0806	0.59	26	0142	-0.58	0.01	1.17	
11	0748	0.92	11	0100	-0.51	0.21	1.42	26	2054	0.45	26	1436	-0.55	-0.05	1.00	
11	1924	0.73	11	1342	-0.48	0.12	1.21	27	0900	0.83	27	0218	-0.37	0.20	1.20	
12	0818	1.06	12	0142	-0.45	0.32	1.51	27	2112	0.56	27	1454	-0.39	0.10	0.95	
12	2048	0.77	12	1442	-0.36	0.21	1.14	28	0854	0.78	28	0242	-0.20	0.27	0.97	
13	0924	1.17	13	0212	-0.29	0.43	1.46	28	2130	0.64	28	1618	-0.25	0.18	0.90	
13	2154	1.04	13	1524	-0.23	0.41	1.26	29	1000	0.66	29	0354	-0.16	0.23	0.82	
14	1000	1.38	14	0406	0.00	0.67	1.38	29	2242	0.53	29	1630	-0.33	0.09	0.86	
14	2242	1.21	14	1630	0.11	0.64	1.10	30	1100	0.58	30	0442	-0.24	0.15	0.82	
15	1100	1.32	15	0448	0.09	0.69	1.23	30	2254	0.54	30	1700	-0.32	0.10	0.86	
15	2330	1.16	15	1724	0.05	0.61	1.11	31	1036	0.54	31	0512	-0.17	0.18	0.71	
16	1142	1.09	16	0618	0.02	0.55	1.07									

# Bathymetry

## 7

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A. Nearshore Profiles. In order to document profile response away from the pier, surveys of four profile lines extending 900 to 1,000 m from shore and located 489 and 581 m north and 517 and 608 m south of the FRF pier are conducted bi-weekly, after storms, and during more complete bathymetric surveys.

These profiles are obtained using a Trimble 4000 GPS for positioning, in combination with the Coastal Research Amphibious Buggy (CRAB), a 10.7 m high, self-powered, mobile tripod on wheels.

Figure 7 shows the last survey in November 1996 and the survey(s) in December 1996 on profile line 188, located 517 m south of the pier.

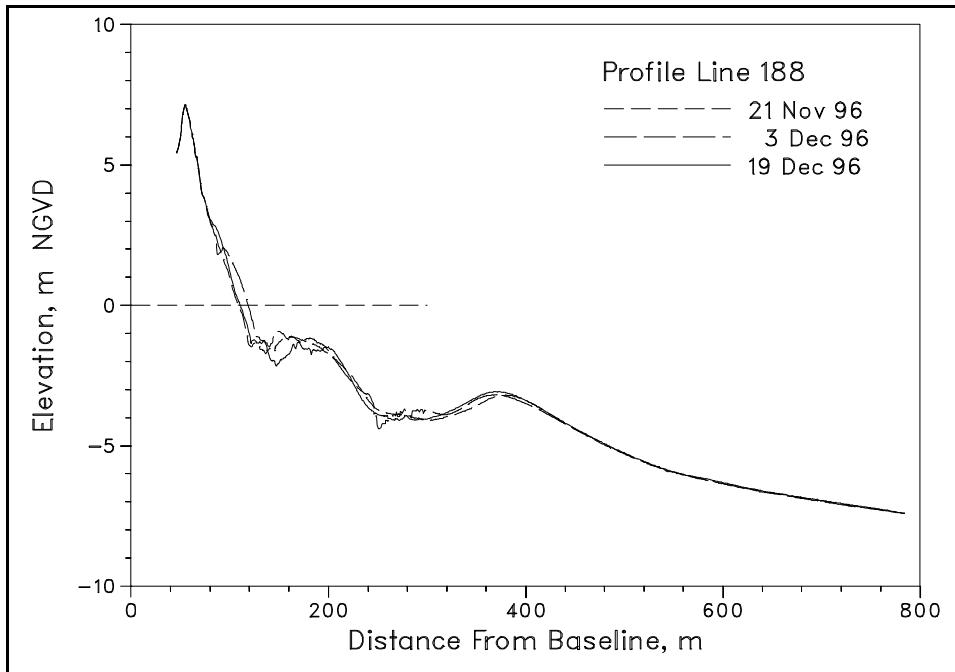


Figure 7. Monthly CRAB Profiles on Profile Line 188.

The profile envelope (Figure 8) reflects the maximum changes that occurred on the profile during 1996. Cross-hatched areas indicate changes to the annual envelope which occurred in December.

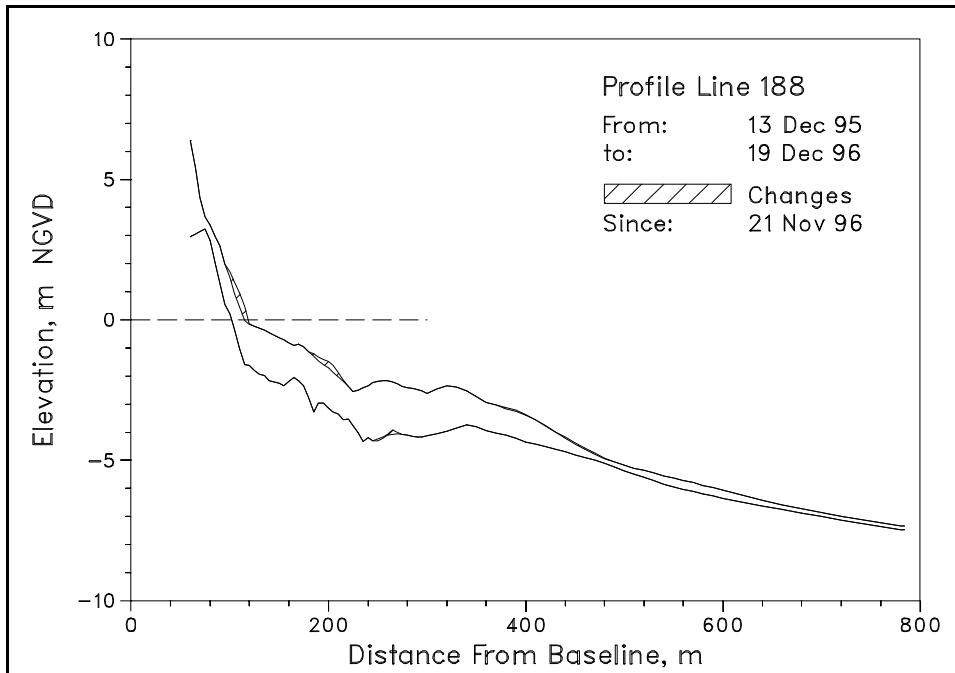
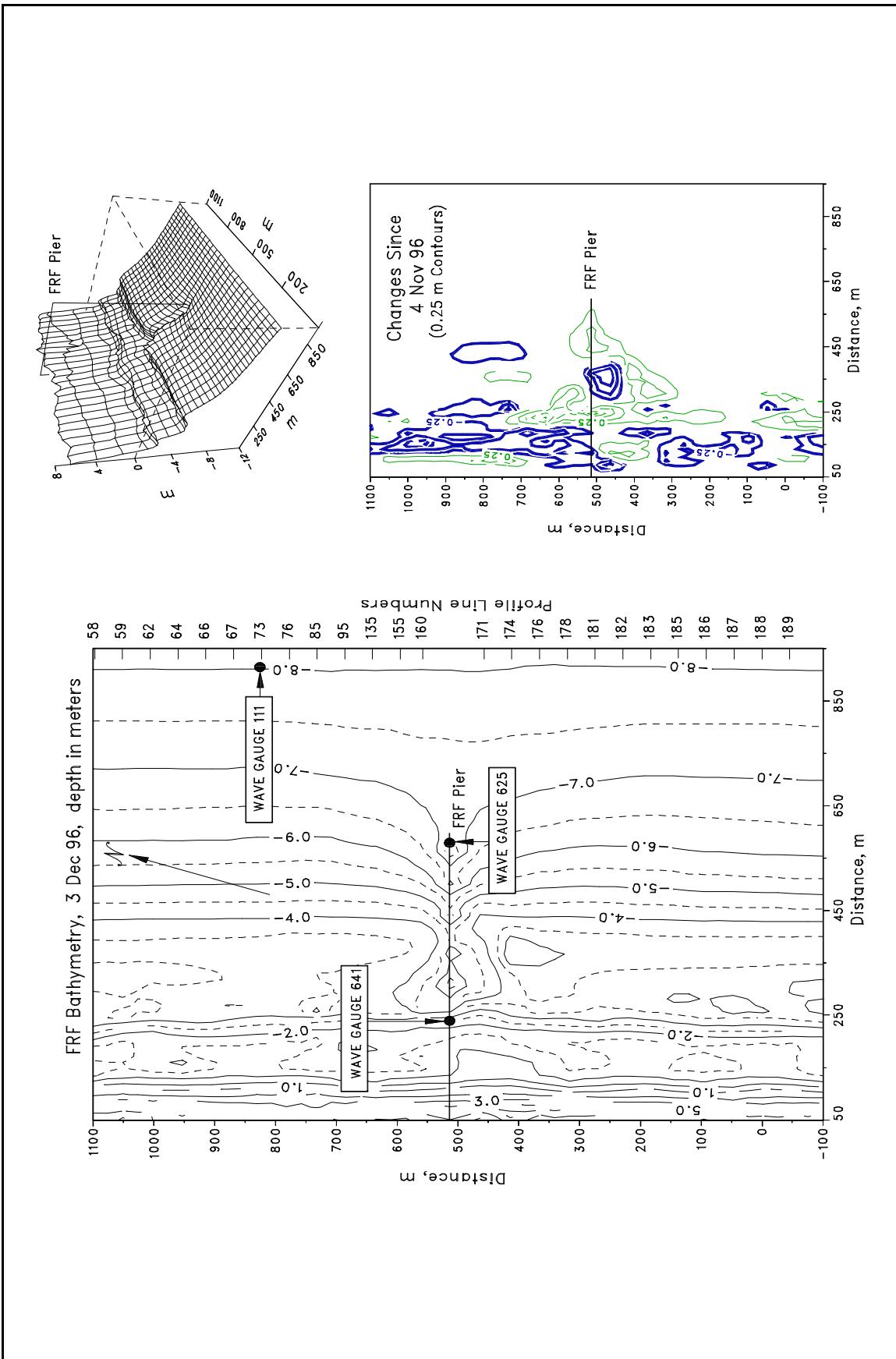


Figure 8. Profile Envelope - Profile Line 188.

B. Bathymetry. Figure 9 includes a two- and three-dimensional contour map and a change plot derived from the bathymetric survey on 3 December. Wide contour lines on the change diagram represent eroded areas; thin lines indicate deposition.



# Special Events

## 8

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A. Storm Data Collection. The following list identifies times when the wave height  $H_{mo}$  at the seaward end of the pier exceeded 2 m.

	<u>Start</u>	<u>End</u>
	14 Dec (1300)	16 Dec (2116)

B. Storm Synopsis.

14-16 Dec Northeasterly winds were funneled between a high pressure system over Ohio and a low pressure system off the Delaware coast. Maximum winds (N) reached 15 m/s at 1600 EST on 15 December. The maximum  $H_{mo}$ , at gauge 625, reached 2.7 m ( $T_p=13.5$  s) at 0208 EST on 16 December. There was no precipitation.